CHAPTER 15

MEASUREMENT OF RESISTANCE (PART 2)

In previous Chapters all values of unknown resistances have been determined by applying Ohm's Law to the readings on voltmeters and ammeters. The disadvantage of this system is that an external source is required and all the testing equipment has to be connected to enable the readings to be taken. The meters and a d.c. supply may have to be transported from place to place to gather the required information. To overcome the disadvantages of the volt-ammeter method of measuring resistance, meters that show the resistance value directly on the meter face have been produced. In some cases an approximate value of resistance only is obtained while in others readings to the fourth decimal place may be read. Most often the degree of accuracy required in the resistance measurement determines the type of instrument to be used.

15.1 OHMMETERS

A simple method of measuring resistance is with an ohmmeter, however, very few meters that read ohms only are now produced. Most multimeters have a resistance scale and because of their versitility they have tended to replace the single function ohmmeter. The electrical circuit that permits the reading of resistance directly from a dial face consists of an internal source, internal resistors and a milliammeter recalibrated to read ohms. (Figure 15.1).

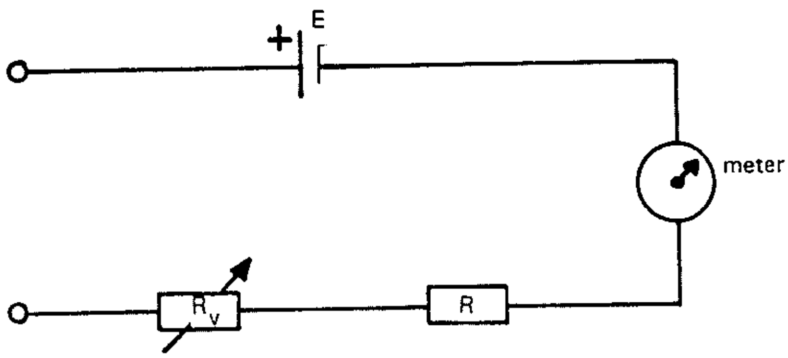

Figure 15.1

The adjustable resistor is used to give the maximum meter deflection when the terminals of the meter are short circuited. This means that the resistance across the meter terminals is as close as possible to zero when the meter indicator is on the **right** hand side of the dial. Thus the scale on the meter must start on the **right hand** side of the meter, not on the **left** hand side, as in all previous meters. The dial on the meter is then calibrated using various values of known resistance across the meter terminals. Ohmmeters are compact and cheap to produce, but have the disadvantage that, due to the fact that the dial must be calibrated from zero to infinity, their readings are only an approximation.

15.2 THE MEGGER

The e.m.f. source of an ohmmeter rarely exceeds 4 to 5 volts. A megger produces an internal e.m.f. which may be as high as 5000 volts, although the most common ranges are 250 volts, 500 volts and 1000 volts. The high voltages are produced by the use of a hand turned generator which is built into the megger. (Figure 15.2)

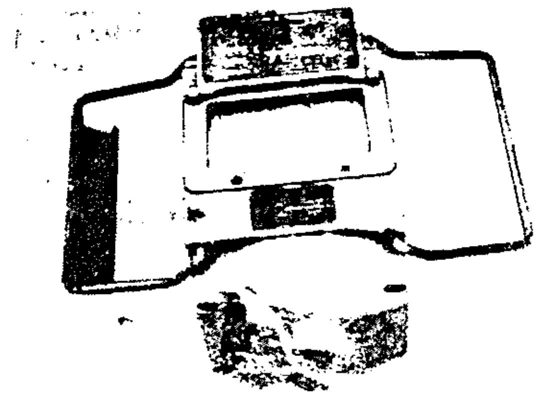

Figure 15.2

This generator is fitted with a slip clutch which limits the speed of the generator so that it produces a constant voltage across its terminals.

The scale on a megger is the same as that on an ohmmeter.

Meggers are used to test for continuity of a circuit ~~and~~ to test the insulation resistance of equipment. In the continuity test the megger is used to find if there is a break in a circuit. If a circuit is continuous the megger reading will be towards the zero end of the scale, while a break, or open circuit, will be indicated by an infinity reading. For insulation testing, one lead from the megger is connected to a conductor while the other lead is connected to metal housing the conductor. The megger then measures the resistance of the insulation that protects the conductor. Common applications of the megger are the measurement of the resistance between conductors and earth in house wiring, electric motors and domestic appliances.

Some meggers up to the range of 500 volts have batteries instead of a generator for their internal supply. The equipment under test is connected to the line and earth terminals and the potential applied by pressing a button on the front of the megger. (Figure 15.3).

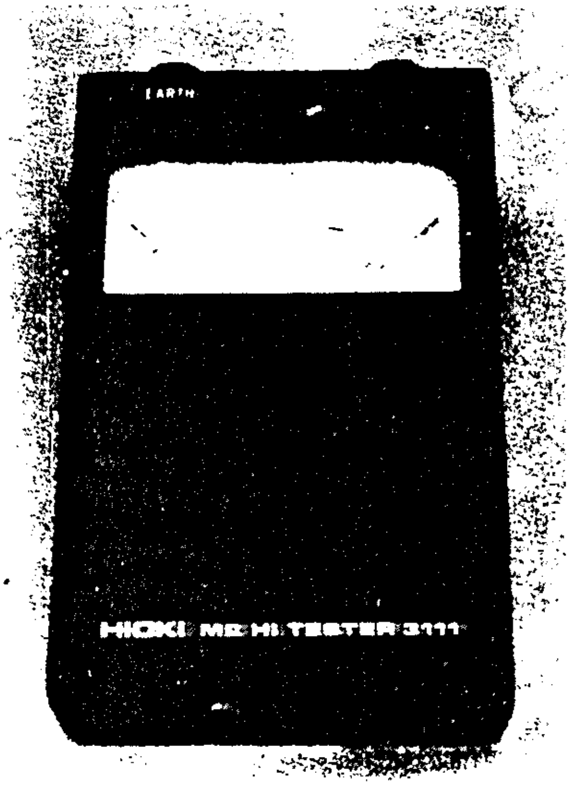

Figure 15.3

Because of their ease of operation, hand operated meggers (as against hand wound meggers) are being increasely used as a method of insulation testing.

15.3 WHEATSTONE BRIDGE

An accurate method of measuring resistance is by the use of a Wheatstone Bridge instrument. (Figure 15.4).

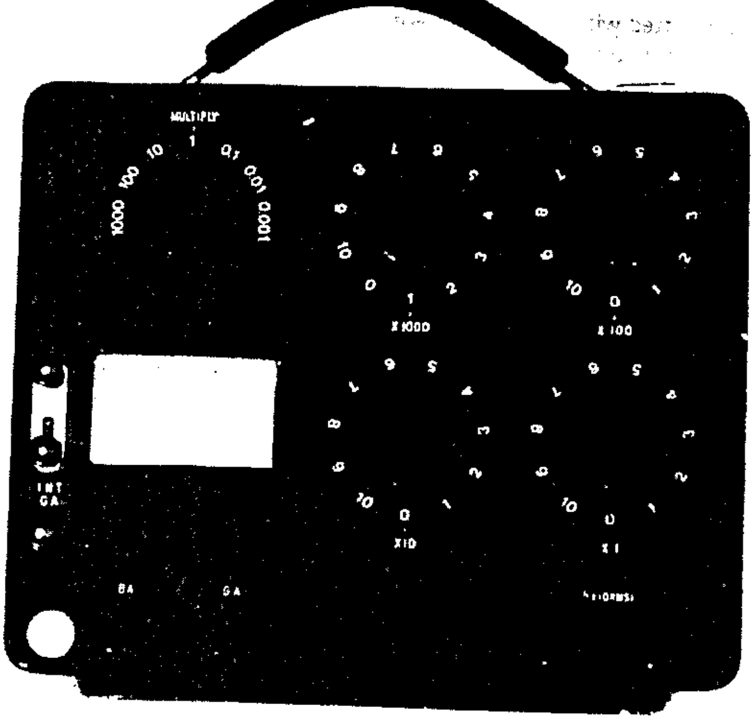

Figure 15.4

A modern Wheatstone Bridge consists of a ratio arm (top left hand corner), four resistor selector dials, a centre zero galvanometer, connecting terminals and two press button switches (BA and GA). The interior contains graded resistors to match the values on the selector switches plus a battery as a source of e.m.f. The circuit for a Wheatstone Bridge is shown in figure 15.5.

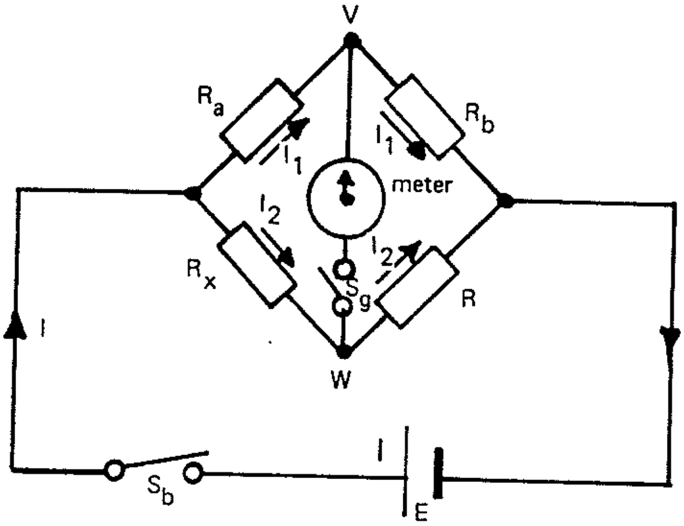

Figure 15.5

The value of the unknown resistance R is determined by balancing the bridge, a condition where zero current exists in the galvanometer circuit when S_B and S_G are closed. Because the value of the unknown resistor R_x is determined when there is zero current in the indicating meter, this method is often referred to as the null method of measuring resistance.

In Figure 15.5, let –

(i) R_a and R_b be fixed resistance values.

(ii) R be a variable resistor.

(iii) R_x be the unknown resistance.

For zero current to flow through the galvanometer with both switches closed, points V and W must be at the same potential. That is, the voltage drop across R_b will equal the voltage drop across R, while the voltage drop across R_a will equal the voltage drop across R_x.

Mathematically this means -

$$I_1 R_b = I_2 R \quad \text{and}$$

$$I_1 R_a = I_2 R_x$$

Dividing the first equation by the second equation gives –

$$\frac{I_1 \ R_b}{I_1 \ R_a} = \frac{I_2 \ R}{I_2 \ R_x}$$

cancelling the currents,

$$\frac{R_b}{R_a} = \frac{R}{R_x}$$

transposing,

$$R_x = \frac{R_a \ R}{R_b} \quad \text{or}$$

$$R_x = \frac{R_a}{R_b} \times R \text{ ohms}$$

When actually using the Wheatstone Bridge instrument R_x is the unknown resistance, which is connected to a pair of terminals of the instrument. The ratio $\frac{R_a}{R_b}$ is called the ratio arm or multiplying factor. The value R is read direct from the resistor selector dials.

Example 15.1

Calculate the value of a resistor being measured by a Wheatstone Bridge that has a nil reading when the ratio arm is set at 10 and the selector dials read 2834.

$R = 2834\ \Omega$

$\frac{R_a}{R_b} = 10$

$R_x = ?\ \Omega$

$$R_x = \frac{R_a}{R_b} \times R$$

$$= 10 \times 2834$$

$$= 28340\ \Omega \quad \text{or} \quad 28.34\ k\Omega$$

The accuracy and range of a Wheatstone Bridge can be improved by a five selector dial bridge.

The five selector dials are known as the measuring arms and are calibrated in ten steps to give -

0 1 ohms	x	9	=	0.9 ohms
1 ohm	x	9	=	9.0 ohms
10 ohms	x	9	=	90.0 ohms
100 ohms	x	9	=	900.0 ohms
1000 ohms	x	9	=	9000.0 ohms
				9999.9 ohms

This gives a minimum reading of 0.1 ohms and a maximum reading of 9999.9 ohms.

The ratio arm selector dial allows multiplying factors of -

x 0.001
x 0.01
x 0.1
x 1
x 10
x 100
x 1000

Combining the measuring arm reading with the ratio arm setting gives a total range for the five selector arm Wheatstone Bridge of 0.0001 ohms to 9.999 Megohms.

The smaller, portable type bridge uses four measuring arm dials and has a range of 1 ohm to 10 megohms. (Figure 15.4).

15.4 OPERATING THE WHEATSTONE BRIDGE

When determining the value of an unknown resistance by the Wheatstone Bridge, the following procedure is adopted.

1. Connect the unknown resistor to the external terminals on the instrument.
2. Set the measurement and ratio dials to the anticipated value of resistance.
3. Close the battery switch (both battery and galvanometer switches are usually push buttons)
4. Close the galvanometer switch.
5. Observe the galvanometer needle to see if the reading is too high or too low.
6. Open the switches and adjust the measuring arm setting.
7. Repeat the previous six steps until the meter needle stays on the centre zero line of the galvanometer.
8. Read off the figures on the measuring arms and multiply by the ratio arm setting.

The advantage of the Wheatstone Bridge is its degree of accuracy, this being as high as 0.1% on the lower range. The disadvantage is that, due to the complexity of the instrument, its cost is much higher than that of an ohmmeter or megger.

15.5 THE METRE BRIDGE

The metre bridge consists of a metre rule, a metre length of resistance wire, an e.m.f. source and a centre zero meter. These are arranged as shown in figure 15.6

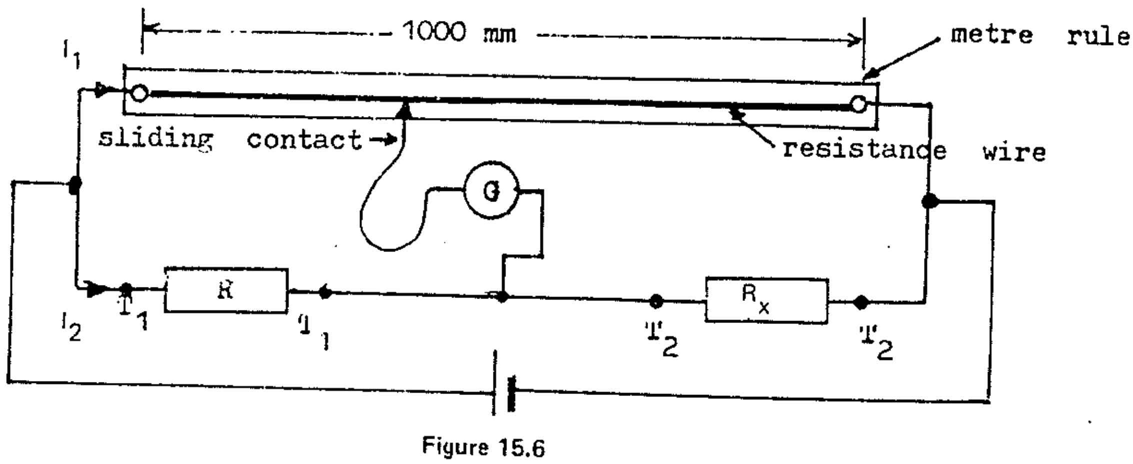

Figure 15.6

A known resistance R and the unknown resistance R_x are connected to the terminals T_1 and T_2. The sliding contact is moved along the wire until a null reading is obtained on the meter. The distance (l_1) the sliding contact is from the left hand end of the meter rule is read straight from the rule. The right distance is determined from $1000 - l$. Using the Wheatstone Bridge principles the following equation may be produced.

When the galvanometer reads zero the voltage drop along the distance l will equal the voltage drop across R

$$I_1 l = I_2 R$$

Likewise the voltage drop along the distance (1000 − l) will equal the voltage drop across R_x.

$$I_1 (1000 - l) = I_2 R_x$$

Dividing the first equation by the second equation

$$\frac{I_1 l}{I_1 R} = \frac{I_2 (1000 - l)}{I_2 R_x}$$

or

$$\frac{l}{R} = \frac{(1000 - l)}{R_x}$$

transposing $R_x = \dfrac{R\,(1000 - l)}{l}$ ohms

Example 15.2

When a metre bridge connected as shown in figure 15.7 is used to determine an unknown resistor, balance was found 252 mm from the left hand end with a known resistance of 50 ohms in the circuit. Calculate 'X'.

$R = 50\ \Omega$

$l = 252$ mm

$(1000 - l) = 748$ mm

$R_x = ?\ \Omega$

$$R_x = \frac{(1000 - l)\,R}{l}$$

$$= \frac{748 \times 50}{252}$$

$$= 148.4\ \Omega$$

TUTORIALS 1.15

(1) In the circuit shown in figure 15.5, A and B have resistances of 100 Ω and 1000 ohms respectively. A decade box used as R gave a reading of 268 ohms when the bridge was balanced. Calculate 'R_x'.

(2) In a circuit similar to figure 15.5 the positions of resistors R and 'R_x' were reversed and the same values of A, B and R used as in the previous tutorial. Calculate 'R_x'.

(3) In a metre bridge circuit, the positions of R and 'R_x' are reversed. Evolve an equation for the unknown resistance 'R_x'.

(4) A metre bridge circuit has a 470 ohm resistor connected to the left hand side of the galvanometer. The galvanometer indicated zero at a point 746 mm from the left hand end of the ruler. Calculate the value of the unknown resistor.

(5) A metre bridge is o constructed that the known resistor of 330 ohms is connected on the right hand side of the galvanometer. The point of balance was reached 425 mm from the left hand end of the ruler. Calculate the value of the unknown resistor.